

SimHumalator

A Human Radar Simulator

1. Important points for deciding the simulation parameters

- i. Range resolution is dictated by the bandwidth swept by the chirp

$$\Delta_r = \frac{c}{2BW}$$

- ii. Maximum range is limited by the ADC sampling frequency f_s

$$R_{max} = \frac{cf_s}{2\gamma}$$

- iii. Doppler resolution depends upon the coherent processing interval

$$\Delta_{f_D} = \frac{1}{T_{CPI}}$$

- iv. Maximum Doppler that can be detected is given by

$$f_{Dmax} = \pm \frac{PRF}{2}$$

$c = 3 \times 10^8$ m/s is the speed of light

$\gamma = \frac{BW}{T_{CD}}$ is the chirp factor

$PRF = \frac{1}{T_{PRI}}$ is the pulse repetition frequency

2. Simulator simulate human radar returns as a function of following parameters-

i. Radar Parameters

1. Radar Waveform Parameters
 - a. Carrier frequency (Hz)
 - b. Sampling frequency (Hz)
 - c. Bandwidth (Hz)
 - d. Pulse Repetition Frequency (PRF)
 - e. Duty Cycle of Chirp
 - f. Coherent Processing Interval (CPI)
2. Configuration of Radar
 - a. Monostatic
 - b. Bistatic Inline
 - c. Bistatic Circular

ii. Target Parameters

1. Activity type
2. File Number (Multiple files within each activity)
3. Aspect angle of target with respect to radar
4. Initial location of target in space

iii. Radar Signatures Generated

1. Baseband digitized radar returns

2. Range-Doppler Maps
3. Range-time Profiles
4. Doppler-time Profiles

3. Demonstration of the simulation

- a. Run the app. The main page of the simulator would be



Select Radar Parameters
Select Target Parameters
Generate Radar Signatures

FMCW Description
Choose FMCW Radar Parameters

Tool to simulate human radar returns as a function of following parameters-

1. Radar Parameters
 - # Carrier frequency
 - # Sampling frequency
 - # Bandwidth
 - # Pulse Repetition Frequency (PRF)
 - # Duty Cycle of Chirp
 - # Coherent Processing Interval (CPI)
2. Target Parameters
 - # Activity type
 - # Aspect Angle wrt radar
 - # Initial radial distance from radar
3. Radar Signal Processing
 - # Generate- baseband digitized radar returns
 - # Range-Doppler Maps
 - # Range-time Profiles
 - # Doppler-time Profiles
4. Save Files
 - # Time domain returns
 - # Range-Doppler Maps
 - # Range-time Profiles
 - # Doppler-time Profiles

Next

- b. Press Next to select radar parameter



Select Radar Parameters
Select Target Parameters
Generate Radar Signatures

FMCW Description
Choose FMCW Radar Parameters

Select FMCW Radar Parameters

Select Frequency Band Select
Default: S Band

PRF (Hz) 1000
Default: 1000Hz

Duty Cycle of Chirp(%) 80
Default: 80

CPI (sec) 0.1
Default: 0.1 sec

Sampling Frequency (Hz) 1e+06
Default: 1e6 (1MHz)

Bandwidth (Hz) 2e+09
Default: 2e9 (2GHz)

Off On

Switch off: Select Default Bands
Switch on: Select User selected band

Center Frequency (Hz) 0
Default: 2.4e9 (2.4GHz)

Pulse repetition frequency PRF
(Must be greater than max Doppler frequency user wants to see)

(Decides chirp duration in PRI)

(Coherent Processing Interval CPI)

(Decides number of fast time samples)

(Decides range resolution)

Previous
Next

c. Bands switch is by default off.

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A Human Radar Simulator

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Default band switch

Select Radar Parameters | Select Target Parameters | Generate Radar Signatures

FMCW Description | Choose FMCW Radar Parameters

Select FMCW Radar Parameters

Select Frequency Band: **Select** (Default: S Band)

Off **On**
Switch off: Select Default Bands
Switch on: Select User selected band

Center Frequency (Hz): (Default: 2.4e9 (2.4GHz))

PRF (Hz): (Default: 1000Hz)
Pulse repetition frequency PRF (Must be greater than max Doppler frequency user wants to see)

Duty Cycle of Chirp(%): (Default: 80)
(Decides chirp duration in PRI)

CPI (sec): (Default: 0.1 sec)
(Coherent Processing Interval CPI)

Sampling Frequency (Hz): (Default: 1e6 (1MHz))
(Decides number of fast time samples)

Bandwidth (Hz): (Default: 2e9 (2GHz))
(Decides range resolution)

Frequency (Hz) | FMCW Waveform

Diagram labels: T_{PRI} , $T_{CPI} = PT_{PRI}$, $T_{Total} = MT_{CPI} = MP T_{PRI}$

Buttons: Previous, Next

d. If band switch is off, then select the frequency from the bands available in the drop-down menu

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Select desired band

Select Radar Parameters | Select Target Parameters | Generate Radar Signatures

FMCW Description | Choose FMCW Radar Parameters

Select FMCW Radar Parameters

Select Frequency Band: **Select** (Default: S Band)

Off **On**
Switch off: Select Default Bands
Switch on: Select User selected band

Center Frequency (Hz): (Default: 2.4e9 (2.4GHz))

PRF (Hz): (Default: 1000Hz)
Pulse repetition frequency PRF (Must be greater than max Doppler frequency user wants to see)

Duty Cycle of Chirp(%): (Default: 80)
(Decides chirp duration in PRI)

CPI (sec): (Default: 0.1 sec)
(Coherent Processing Interval CPI)

Sampling Frequency (Hz): (Default: 1e6 (1MHz))
(Decides number of fast time samples)

Bandwidth (Hz): (Default: 2e9 (2GHz))
(Decides range resolution)

Frequency (Hz) | FMCW Waveform

Diagram labels: T_{PRI} , $T_{CPI} = PT_{PRI}$, $T_{Total} = MT_{CPI} = MP T_{PRI}$

Buttons: Previous, Next

- e. If ON, then enter desired center frequency for FMCW waveform



Enter desired center frequency



Select Radar Parameters | Select Target Parameters | Generate Radar Signatures

FMCW Description | Choose FMCW Radar Parameters

Select FMCW Radar Parameters

Select Frequency Band: (Default: S Band)

Center Frequency (Hz): (Default: 2.4e9 (2.4GHz))

PRF (Hz): (Default: 1000Hz)

Duty Cycle of Chirp(%): (Default: 80)

CPI (sec): (Default: 0.1 sec)

Sampling Frequency (Hz): (Default: 1e6 (1MHz))

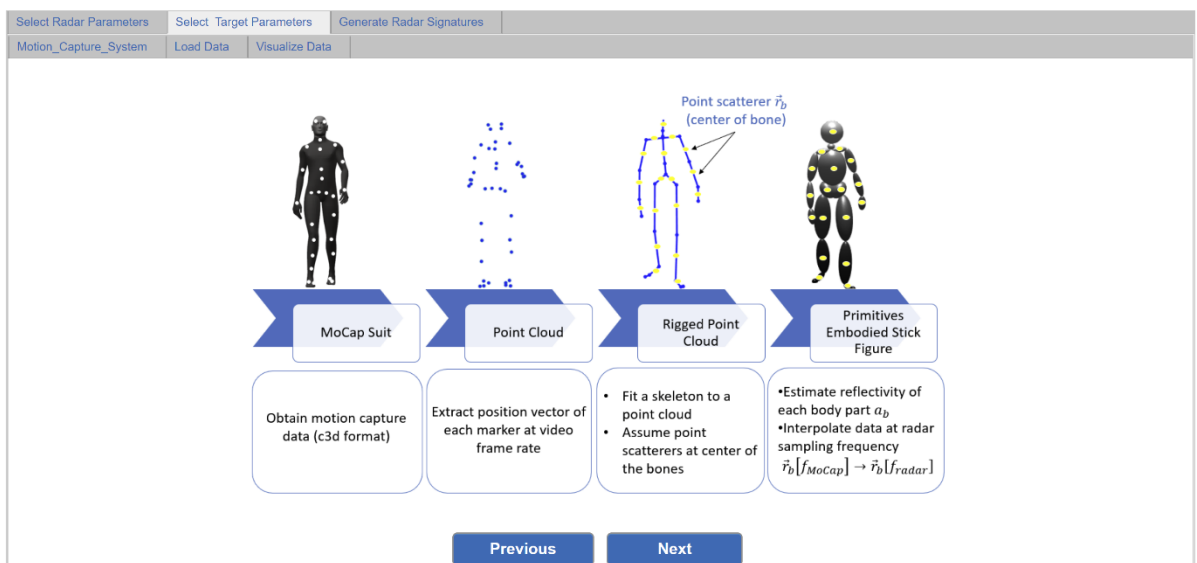
Bandwidth (Hz): (Default: 2e9 (2GHz))

Switch: Off On (Switch off: Select Default Bands; Switch on: Select User selected band)

Frequency (Hz) FMCW Waveform diagram showing chirps p=1 to p=MP over time, with parameters T_{PRI} , $T_{CPI} = PT_{PRI}$, and $T_{Total} = MT_{CPI} = MPT_{PRI}$.

Buttons: Previous, Next

- f. Enter other parameters such as PRF, Duty cycle, CPI, Sampling frequency and Bandwidth. If not entered, will select the default values
- g. Press Next to enter target parameter selection tab. This tab shows the simulation methodology to generate target data based on motion capture system



h. Press Next to load target data

The screenshot shows the SimHumalator interface with the following elements:

- 1 Radar Configuration:** Radio buttons for Monostatic, Bistatic Inline, and Bistatic Circular.
- 2 Human Activity:** A dropdown menu currently showing "Select".
- 3 File Number:** An input field containing the number "1".
- 4 Max Number of Files Available (for selected activity):** An input field containing the number "1".
- Load:** A blue button to load the data.
- Target Trajectory:** A 2D plot with X (m) and Y (m) axes ranging from -4 to 4. The plot is currently empty.
- Change Target Trajectory (optional):** A panel with various parameters:
 - Target Properties:** Aspect Angle (Degrees) [0], Initial Location (m) [X: 0, Y: 3, Z: 0], Baseline Length (m) [X: 0, Y: 0, Z: 0], Bistatic Angle (Degrees) [0].
 - Radar Properties:** Tx Location (x,y,z) (m) [0, 0, 0], Rx Location (x,y,z) (m) [0, 0, 0].
 - Figure Properties:** X Limits [min: 0, max: 0], Y Limits [min: 0, max: 0].
- Change:** A blue button to apply the target trajectory settings.
- Navigation:** "Previous" and "Next" buttons at the bottom.

i. First select the desired radar configuration

Radar Configuration Monostatic Bistatic Inline Bistatic Circular

ii. Select the desired activity from the drop-down menu

The close-up shows the "Human Activity" dropdown menu with the following options: Select, Walking, Punching, Kicking, Bodyrotating, and Grabbing. The "Grabbing" option is highlighted. The "File Number" field is set to 1 and the "Max Number of Files Available" field is set to 10.

- iii. Once the activity is selected, the box marked red in 3 will display the number of files available in each activity category. For instance, Human body rotating has 10 files. User can enter the file number to generate data corresponding to a file.**
- iv. file number is entered, hit the load button. Figure on the bottom will display the human position in space with respect to radar**

Select Radar Parameters | Select Target Parameters | Generate Radar Signatures

Motion_Capture_System | Load Data | Visualize Data

Radar Configuration Monostatic Bistatic Inline Bistatic Circular

Human Activity:
 File Number: Max Number of Files Available (for selected activity):
 Loading Completed

* Rotate to change figure view

Default Trajectory

Change Target Trajectory (optional)

Target Properties

Aspect Angle (Degrees): Aspect angle of target with respect to radar

Initial Location (m): X: Y: Z: X: target X location in space, Y: target Y location in space, Z: target Z location in space

Baseline Length (m): Bistatic Inline Configuration X: Y: Z: X: Length along X in space, Y: Length along Y in space, Z: Length along Z in space

Bistatic Angle (Degrees): Bistatic Circular Configuration Bistatic angle of target with respect to radar

Radar Properties

Tx Location (x,y,z) (m): X: Y: Z:

Rx Location (x,y,z) (m): X: Y: Z: Rx location will be automatically updated

Figure Properties

X Limits: min max Y Limits: min max

Change

Previous Next

- v. Change the target trajectory parameters from the panel on the right-hand side and press change button. Once changes are fixed, press Next button.
- i. Next page displays the ground truth signatures of the target- range-time and velocity-time.



Select Radar Parameters | Select Target Parameters | Generate Radar Signatures

Motion_Capture_System | Load Data | Visualize Data

Ground Truth Signatures

Ground Truth Range-time plot

Ground Truth Velocity-time plot

Select Desired Time (Optional)

Start time (sec): Stop time (sec):

Generate Profiles

Range-Time

Velocity-Time

Previous Next

- j. If want to capture the entire data, then directly press Next button otherwise first enter the start time and the stop time to select the desired duration then, press Generate Profiles button. Once desired time duration is selected, press Next button.

Select Radar Parameters | Select Target Parameters | Generate Radar Signatures

Motion_Capture_System | Load Data | Visualize Data

Ground Truth Signatures

Select Desired Time (Optional)

Start time (sec) Stop time (sec)

Generate Profiles

Previous Next

k. This page belongs to radar signatures tab. Press **Generate Time Domain Data** to generate the radar returns from dynamic human activity for a selected configuration of radar

Select Radar Parameters | Select Target Parameters | Generate Radar Signatures

Generate Time Domain Returns | Generate Range Doppler Maps | Generate Range Time Plots | Generate Doppler Spectrograms

Generate Time Domain Data

Save Time Domain Radar Returns

File Format **Save**

File generated would have the following details:
 1. Folder generated- Current Directory\Results\Date\Radar Time Domain Returns\filename
 2. Filename: activityname_filename_carrierfreq_val_sampling_freq_val
 3. Fields saved- time domain radar returns, PRI, CPI, Sampling time

Baseband Digitized Radar Data at Rx ($Y[N T_s, M P T_{PRI}]$)

N: Number of fast time samples in a PRI
P: Number of PRIs in a T_{CPI}
M: Number of CPIs in total time T_{Total}

Previous Next

l. Once generated, select the file format for saving the time domain radar returns

Select Radar Parameters | Select Target Parameters | **Generate Radar Signatures** | Generate Time Domain Returns | Generate Range Doppler Maps | Generate Range Time Plots | Generate Doppler Spectrograms

Completed

Save Time Domain Radar Returns

File Format: **Select** Select **Save**

File generated would have the following details:
 1. Folder generated- Current Directory/Results/Date/Radar Time Domain Returns/filename
 2. Filename- activityname_carrierfreq_val_sampling_freq_val
 3. Fields saved- Range, PRI, CPI, Sampling time

File formats: **.mat**, **.csv**, **.txt**

Baseband Digitized Radar Data at Rx ((N, M, P, T_{PRI}))

N: Number of fast time samples in a PRI
P: Number of PRIs in a T_{CPI}
M: Number of CPIs in total time T_{Total}

Previous **Next**

m. Press Next to generate Range-Doppler Maps. Users can save the range-Doppler maps from the drop-down menu.

Range-Doppler Maps

Want to change properties of RD Maps ?

Choose X Limits: min max Min and max Doppler velocity (m/s) (if not entered will pick original range)

Choose Y Limits: max Max Range (if not entered will pick original range)

Dynamic Range (dB): max Dynamic range of signal strength (max is by default max strength of signal)

RD Map for CPI Num:20

Save Range-Doppler as images? Yes No

Completed

Range-Doppler Processing

Save Range-Doppler Maps

File Format: **Select** Select **Save**

File generated would have the following details:
 1. Folder generated- Current Directory/Results/Date/Radar Doppler Maps/filename
 2. Filename- activityname_filename_carrierfreq_val_BW_val_CPI_num
 3. Fields saved- RD Maps, Range axis, Velocity Axis, Number of CPI

Previous **Next**

If not entered will pick default values based on the selected radar parameters

n. Next page will generate the range-time profiles. Please note that if the values are not entered, default values will be picked up for the dynamic range, axis limits. Users can change the axis limits.

Range-Time Plot

Do you want to change properties of Range-time Plots ?

Choose Y Limits max Choose max range user wants to see (if not entered will pick original range)

Dynamic Range (dB) Dynamic range of signal strength (max is by default max strength of signal)

Completed

Range-Time Processing

Baseband Digitized Radar Data at Rx → FFT Along Fast Time → Range-time Data

Save Range-time Data

File Format Save

File generated would have the following details:
 1. Folder generated- Current Directory\Results\Data\Radar Time Plots\filename
 2. Filename: activityname_filename_carrierfreq_val_BW_val_CPI_num
 3. Fields saved- Range axis, time axis, Range-time data

Previous Next

o. Next page will generate the Doppler-time plots. Please note that if the values are not entered, default values will be picked up for the dynamic range, axis limits and short time window. Users can change these values.

Generate Radar Returns and Spectrograms

Short time window (sec) Change this window based on motion type (If slow activity- keep it high 0.5sec) (If fast- keep it around 0.1sec)

Dynamic Range (dB) Dynamic range of signal strength (max is by default max strength of signal)

Choose Y Limits min max Min and max Doppler frequency user wants to see (if not entered will pick original range)

Generated

Doppler-Time Processing

Baseband Digitized Radar Data at Rx → STFT Along Slow Time → Doppler spectrogram

Save Spectrograms

File Format Save

File generated would have the following details:
 1. Folder generated- Current Directory\Results\Data\Radar Spectrograms\filename
 2. Filename: activityname_filename_carrierfreq_val_sampling_freq_val
 3. Fields saved- Spectrogram, time axis, Doppler axis

Previous

4. Saved Files

Please note that the files will be saved in the current directory of the simulator. Folders would be generated independently for each signature type- time domain returns, range-time data, Doppler-time data, range-Doppler data. Withing each of these folders, another folder would be generated corresponding to the selected target activity and the file number corresponding to the selected activity. Detailed description of file being saved is given below the save button.